2011

Self-Encoded Spread Spectrum for Multirate Multimedia Communication in Multipath Channel

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Self-Encoded Spread Spectrum for Multirate Multimedia Communication in Multipath Channel

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***Abstract*—In this paper, we propose the self-encoded spread spectrum (SESS) with multirate multimedia communication in multipath channel. In multirate multimedia SESS system, each application has their own transmission bit rate. The signal is transmitted through multipath channels each with different channel gain and time delay. We view the main path as the signal resource and other paths as interference. At the receiver side, decorrelation scheme is employed for the main path combined signal not only to reduce the crosstalk between different applications, but also to provide a better estimation for the despreading sequence in the main path. Interference cancellation(IC) in the main path is adopted to improve the correlation detection and iterative detection(ID) performance. Finally the ID is employed to improve the bit error rate (BER).**

***Index Terms*—Multirate, multimedia, decorrelation, interference, iterative detection and self-encoded spread spectrum.**

I. Introduction

Multimedia is the media that uses multiple forms of information content and information processing (e.g. text, audio, graphics, animation, video, interactivity) to inform or entertain the user. It is similar to traditional mixed media in fine art, but with a broader scope. The term ”rich media” is synonymous for interactive multimedia. Multimedia may be broadly divided into linear and non-linear categories. Linear active content progresses without any navigation control for the viewer such as a cinema presentation. Non-linear content offers user interactivity to control progress as used with a computer game or used in self-paced computer based training. Non-linear content is also known as hypermedia content. Multimedia finds its application in various areas including, but not limited to, advertisements, art, education, entertainment, engineering, medicine, mathematics, business, scientific research and spatial, temporal applications [1]. In this paper, we employ multirate multimedia transmission with self-encoded spread spectrum in multipath channels. Multirate means each application in the communication system has its own transmission bit rate. Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. It can be viewed as the reception of multiple copies of the same source signal.

The SESS multiple access model is presented in [2]. Chip-interleaved multiple access with iterative detection is shown in [3]. SESS with time hopping pulse position modulation in ultra wideband is studied in [4] where the SESS performance is remarkably improved compared to the binary phase-shift keying (BPSK). Multirate and multimedia self-encoded spread spectrum in flat fading channel was presented in [5] where each application is assigned the spreading sequence with the same length, and multipath is not considered in the model. In our paper, we extend the result in [5] into the multirate multimedia communication in multipath channel. SESS employs a time-varying spreading sequences. SESS needs to update the despreading sequence simultaneously. From [2], in the single user case, the estimation of the despreading sequence is not accurate due to the self-interference caused by the erroneous detection at the receiver. The multirate situation will only aggravates the situation. Another problem in multirate multimedia SESS is the iterative detection for each application. In single user case, iterative detection works well without considering the interference from other application. In SESS with same transmission bit, the interference cancellation (IC) can be employed directly. After IC, the matched receiver processes their own channel output which is prepared for iterative detection. in the multirate case, we cannot use the IC directly because of the high error rate of the multirate correlation detection output due to the interference from other applications. In addition, multipath makes the situation worse for both despreading sequence estimation and iterative detection. In this paper, we consider the sub-path signal as interference assuming that their signal power is much weaker than the main path. Under this assumption, when receiving the signal combined with other application and multipath interference, the first method employed at the receiver is decorrelation for the signal coming from main path. After decorrelation, the combined signal is separated for each application which is more as input to the IC and despreading sequence estimation in the main channel. Finally we can see that the multirate system is more vulnerable than the single user and single rate SESS. We need much more techniques to make the system robust and efficient.

The rest of this paper is organized as follows. In section II, we present the mutilrate multipath SESS system model for both transmitter side and receiver side. At the receiver side, we employ the decorrelation detection, interference cancellation and iterative detection for each application. Especially,in decorrelation detection, we propose a special extended signature vector (ESV) for spreading signature [6]. In section III, We presents the simulation result for three application multirate multimedia transmission in multipath channel.

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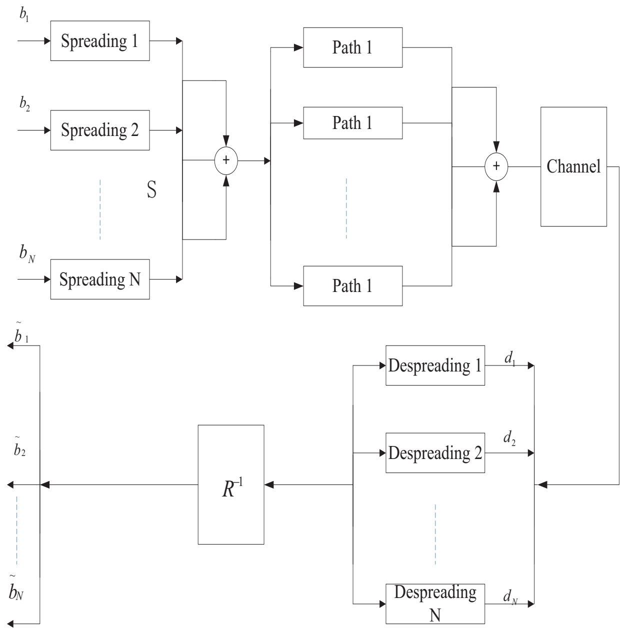

Fig. 1. Multirate Multipath SESS system.

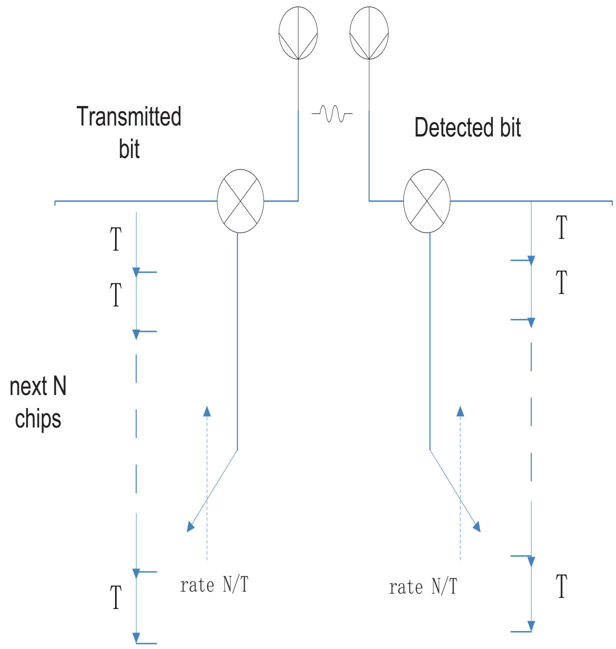

Fig. 2. SESS Transmitter and Receiver.

II. System Model

Fig. 1 presents an example diagram of multirate multipath SESS communication, where every application has its own bit rate. The combined signal from different application and delayed paths undergo the decorrelation to remove the cross interference (CI) between the applications in the main path. The separate signal then can be employed to the iterative detection to improve the BER performance. In this paper, we consider three applications and three paths for simple presentation. The chip length of each applications are 64 chip/bit, 32 chips/bit, and 16 chips/bit. All the applications undergo the same fading and noise in the same path for the same time period, and different paths will have different fading and noise.

A realization of the self-encoding principles is illustrated by the simplified schematic in Fig. 2. As the term implies, the spreading code is obtained from the random digital information source itself. At the transmitter, the delay registers are constantly updated from an N-tap delay of the data, where N is the spreading length. The delay registers generate the code chips that switch at N times the data rate for signal spreading. The self-encoding operation at the transmitter is reversed at the receiver. The recovered data are fed back to the N-tap delay registers that provide an estimate of the transmitter's spreading codes which is called despreading sequence that is required for signal de-spreading. Data recovery is by means of a correlation detector. Notice that the contents of the delay registers in the transmitter and receiver should be identical at the start of the transmission. This is accomplished as part of the initial synchronization procedure [2].

The multirate transmission is shown in detail in Fig. 3. There are three applications in our multirate communication system. Application-1 is 4 chips/bit transmitting four bits during one transmission time period. Application-2 is 8 chips/bit transmitting two bits during one transmission time period. Application-3 is 16 chips/bit transmitting one bit during one transmission time period. Therefore, there are seven bits transmitted in total during one transmission time period. Assuming that the instant fading is $\lambda(t)$, the vector of received signal $\mathbf{r}(t)$ is

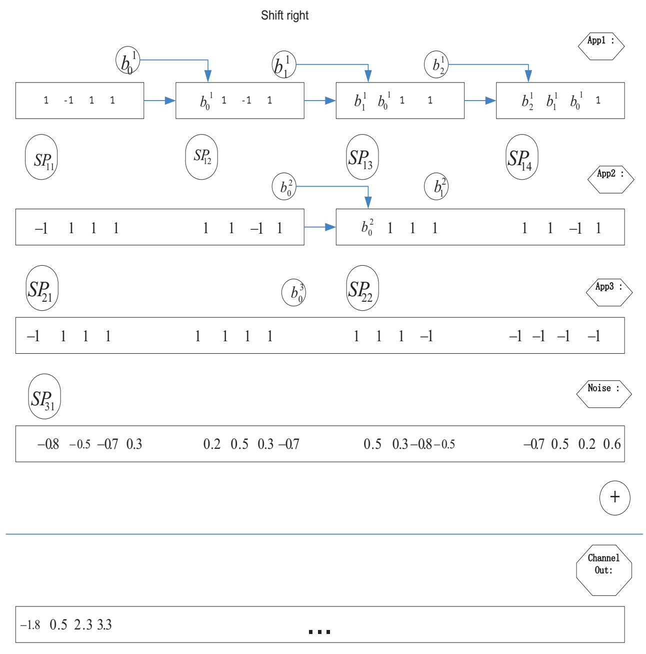

Fig. 3. SESS Multirate System Transmission at the Transmitter.

$$\mathbf{r(t)} = \lambda(\mathbf{t})\mathbf{S}\mathbf{b} + \mathbf{n} \tag{1}$$

In our example from Fig.3, $\mathbf{r}(t)$ is a 7×1 vector, $\mathbf{S}$ is 7×16

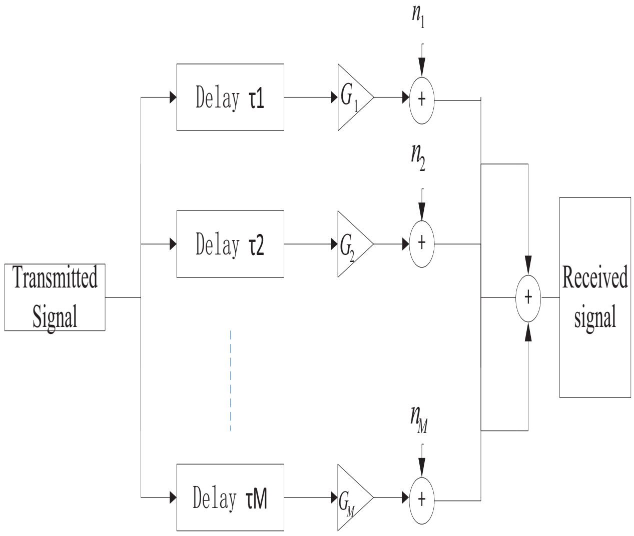

Fig. 4. Multirate and Multimedia SESS in Multipath Channel.

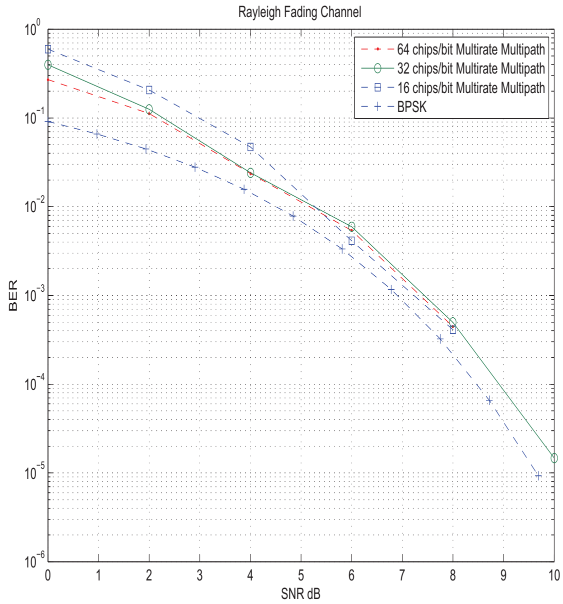

Fig. 5. The performance of decorrleation detection in the multirate communication system in AWGN channel.

matrix, representing the spreading sequence matrix of each application shown as

$$\mathbf{S} = \begin{pmatrix} sp_{11} & 0_{1,8} & 0_{1,4} \\ 0_{1,4} & sp_{12} & 0_{1,8} \\ 0_{1,8} & sp_{13} & 0_{1,4} \\ 0_{1,8} & 0_{1,8} & sp_{14} \\ sp_{21} & 0_{1,4} & 0_{1,4} \\ 0_{1,4} & 0_{1,4} & sp_{22} \\ & sp_{31} & \end{pmatrix} \quad (2)$$

$\mathbf{b}$ stands for transmitted bits with size of 7×1,

$$\mathbf{b} = \begin{pmatrix} b_{11} \\ b_{12} \\ b_{13} \\ b_{14} \\ b_{21} \\ b_{22} \\ b_{31} \end{pmatrix} \quad (3)$$

and $\mathbf{n}$ is the white noise with size of 7×1.

Fig. 4 presents the multirate multimedia SESS in multipath channels for all applications. The multirate combined signal undergoes multiple paths from the source to the destination. The path which contains the strongest signal is called the main path and other path is called the sub-path. The ith sub-path experiences the time delay, τ_i, comparing with the main path. We can assume the delay in the main path, $\tau 1 = 0$. In our simulation, we present total three paths with channel gains, $G_1 = 1$, $G_2 = 0.1$ and $G_3 = 0.05$. The corresponding delays normalized to the chip time, i.e., τ_i for $i = 1, 2, 3$ are integer following the uniform distribution over [0, 15] (within the maximum spreading sequence length). Therefore, the channel impulse response can be shown as

$$h(t) = \delta(t) + 0.1\delta(t - \tau_1) + 0.05\delta(t - \tau_2) \quad (4)$$

III. Numerical result

Figs. 5 and 6 show the bit error rate of decorrelation detection for additive white Gaussian noise (AWGN) channel and Rayleigh fading channel with frequency selective multipath, respectively. The interference effect of multirate multimedia SESS is shown as a half dB at moderate and high signal-to-noise ratio (SNR) in Fig. 5. The interference effect is negligible in Rayleigh fading channel for SNR greater than 15 dB. At low SNR, the BER degradation due to the self-interference is obvious for both channels. The performance degradation without decorrelation is significant in Rayleigh fading channels as shown in Fig. 7. For the SESS without decorreation, we can observe the BER floor for SNR greater than 15 dB while the BER of the multirate multimedia SESS with decorrelation detection still decreases linearly with the SNR. Figs. 8 and 9 exhibit the BER performance of the multirate and multimedia SESS with iterative detection. The BER improvement of the multirate SESS over BPSK is obvious in both channels. As the spreading length increases the BER performance improves significantly for both channels compared to the BPSK channel. The BER improvement of the multirate SESS with iterative detection is more remarkable in Rayleigh fading channels where all applications' BER is better than that of the BPSK and the effect is more significant at high SNR.

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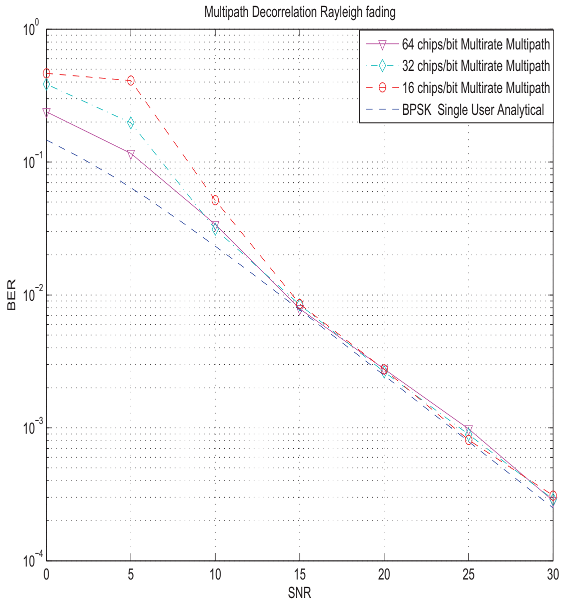

Fig. 6. The performance of decorrelation detection in the multirate communication system in Rayleigh fading channel, multipath.

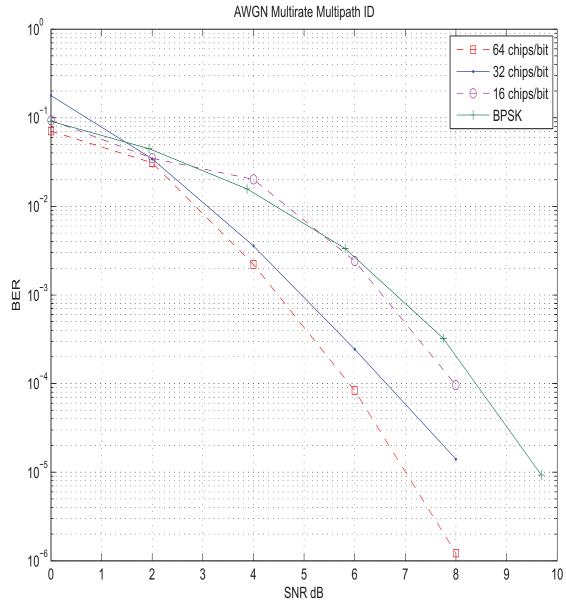

Fig. 8. The performance of iterative detection in the multirate communication system in AWGN channel.

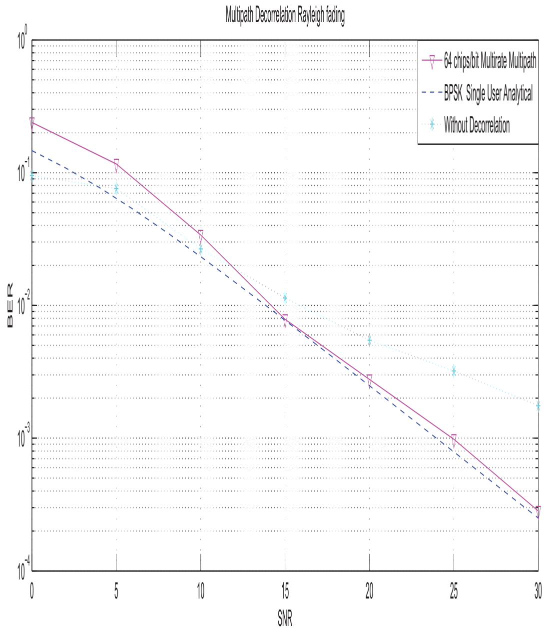

Fig. 7. The comparison of decorrelation detection and without decorrelation detection in the multirate communication system in Rayleigh fading channel, multipath.

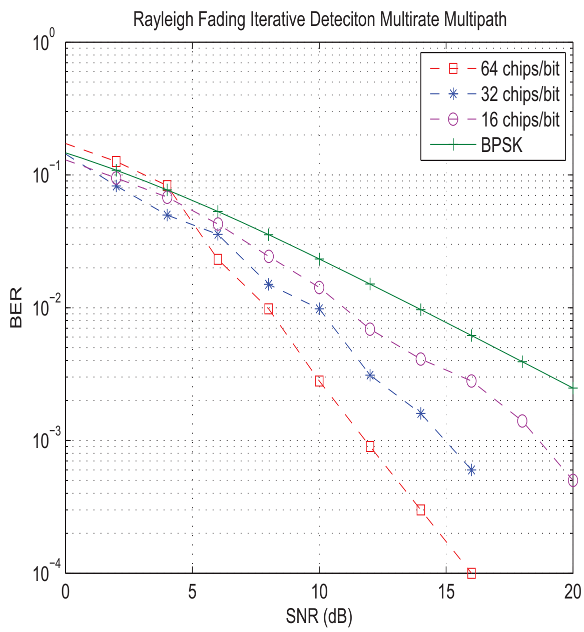

Fig. 9. The performance of iterative detection in the multirate communication system in Rayleigh fading channel, multipath.

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